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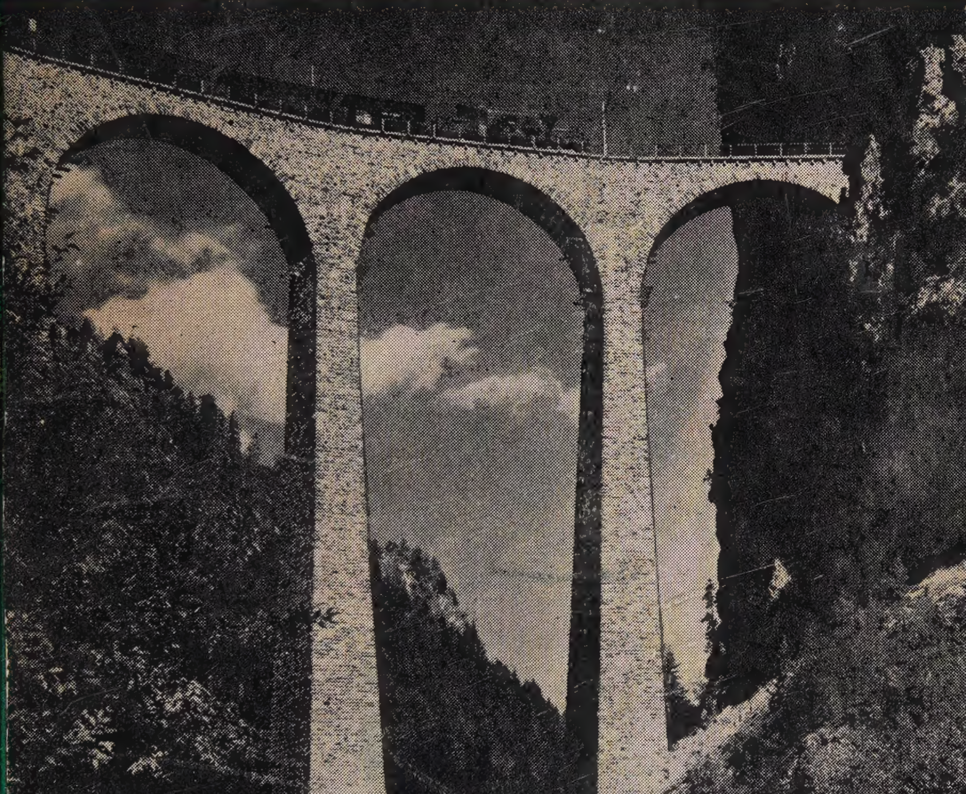
by BEATRICE J. HURLEY



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BRIDGES AND TUNNELS

by BEATRICE J. HURLEY

UNIT STUDY BOOK No. 514

Bridges and Tunnels

By BEATRICE J. HURLEY
Horace Mann School, New York City

I. General Organizing Theme: Man's Increasing Control Over Nature

II. Aspects of the Theme:

A. How man has increased his control over nature through the application of scientific knowledge and methods

B. How science has taught man ways of overcoming distance and time resulting in the development of transportation

III. Learning Elements:

A. When roads were young

B. Early bridges: log, grapevine, covered wooden

C. How bridges differ

1. Materials used: wood, stone, iron and steel, concrete
2. Kinds of bridges to fit different purposes
    a. Iron or wooden beam
    b. Truss
    c. Arch
    d. Cantilever
    e. Suspension
    f. Movable

D. Covered bridges

E. Famous bridges of today

F. How a bridge is run

G. Interesting tunnels

Understanding of the above generalizations and learning elements should be developed by means of numerous group and individual activities.

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Bridges and Tunnels

When Roads Were Young

Time was when few people ventured far from home. The reasons for staying close to home were many. Dangers beset travelers on every hand. Roads were poor and ways of traveling were poorer.

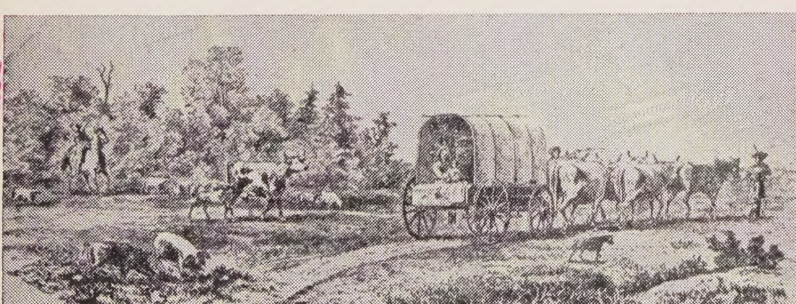
The pioneers pushed their oxen westward. Broad rivers and high mountains blocked their way. There were no bridges spanning the streams. The pioneers searched both upstream and downstream for a fording place. Their heavy oxen plunged into the stream and floated the boatlike Conestoga (kŏn-ĕs-tō′gȧ) wagons* across to the other side. If the streams were swift and deep, lives were often lost.

High mountains were equally troublesome to those early travelers. The low mountains could be crossed. The higher ones could not. Mile after mile the pioneers trudged to find a pass through which the wagons could be pulled to the opposite side.

Rivers and mountains! As long as these two great barriers (băr′ĭ-ẽrs) existed, so long was travel very difficult. Man had to do something about it. He had to overcome these obstacles. And he did.

It took many years to learn how to build strong bridges over the wide rivers. It took still longer to learn how to tunnel under mountains and to make an opening large

*These wagons were given this name because they were built at Conestoga, Pennsylvania.



Wagon trains of the pioneers forded streams as they came to them.

enough for a railroad train. If you were to build a bridge across a stream today, how would you start? You might start by putting a plank across. Then you might put in strong supports beneath. Years ago, men started in much the same way.

Today we forget that beautiful bridges and safe tunnels were not always here. We forget that the waters of the wide Mississippi flowed down to the sea for centuries before the mind of man found a way to span this stream. We even forget that our fast trains did not always hurry through dark tunnels to the opposite side of the high mountains.

Many people travel today. Everyone travels with greater ease and comfort than our forefathers were able to do. The story of how man has built bridges and tunnels is only one part of the great story of transportation. It is only part of the giant struggle which man has made to improve his life upon the earth.

Primitive man early learned to set up or build crude bridges by which he could cross streams. First, he probably used a log. Sometimes a grapevine stretched from a tree on one side of the river to a tree on the other side. Men crossed on such bridges, too. Today we can guess that uncivilized man crossed bridges in this way because we can find bridges like these in the jungles of South America and Africa.

In various parts of the world, men began building bridges out of the materials closest at hand. Men early took the natural grapevine bridge as a model. They took vines and wove bridges of their own. These sometimes looked like hammocks swung across the stream. Today we call them hammock bridges. In Japan and India, men built bridges out of light bamboo poles. Where trees grew large and tall, men used the logs propped against one another.

As time went on, men learned more and more about bridgebuilding. Yet you may be surprised to know that some of our biggest bridges today are built in much the same way as some of these primitive bridges. As you read more about bridges, you will learn which of today's bridges are like grapevines. You will learn which bridges are like the first logs thrown across a stream. From these first simple types, men have learned to build the great and beautiful bridges with which we are familiar today.

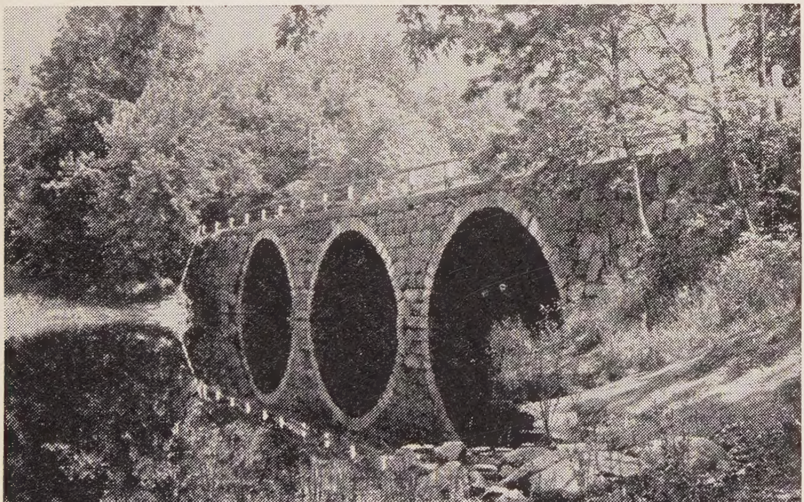
Early Bridges

At one time there were no bridges in our own country. Small streams were crossed by wading them. Sometimes a log was thrown across the stream. The Indians and early settlers had to balance themselves carefully as they walked across these crude log bridges.

The swift, wide streams were not so easy to cross. The early pioneers followed the trails of the elk, the deer, and other animals and the paths of the Indians. These trails usually led to shallow fording places in the streams. Oxen plunged in and forded the stream, hauling the heavy wagons behind them. Many a precious load of family belongings was drenched in such a crossing.

You can readily see that as long as these hardships faced the pioneers there would be very little traveling for pleasure. Something had to be done. As late as 1784 there was not a stone bridge to be found anywhere in the United States.

About this time a famous turnpike was built in Pennsyl-



THE HAMILTON IPSWICH SPAN IN MASSACHUSETTS
Bridges like this were built on the Lancaster Pike.

vania. It was a marvel of crushed stone over which the famed Conestoga wagons clattered by the dozens on their way to Ohio.* The pike ran from Philadelphia to Lancaster, a distance of 66 miles. Along this pike, stone arch bridges were built over the streams. These were among the first real bridges in America.

Another turnpike was built shortly afterward. It was the National Pike, starting at Baltimore and going through the Cumberland Valley to Ohio. Here was indeed the gateway to the Golden West. This turnpike had some stone arch bridges and also the first iron bridge built in America. What a procession passed over this wonderful road! Ox and horse teams hauled the wagons; sheep, cattle, hogs were driven overland by riders on horseback.

The larger streams were not so easily bridged. Stone was not suitable. Engineers turned to wood for material. Great tall timber grew in abundance. Wood was cheap. Why not use it to build a bridge across the stream? So it was that our

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*A turnpike in olden times was a road with frequent tollgates. Persons who wished to go through the gate had to pay a toll or tax.

First Steps in Building a Simple Log Bridge

A drawing of the Old London Bridge which was built in the twelfth century. Houses were built on the bridge, and the roadway was in the center.

lovely covered bridges came to be built. You will read more about them in a separate chapter of this book.

Soon engineers started to use iron and steel for bridges. The first steel bridge was built across the broad Mississippi at St. Louis. The man who built it, Captain James Eads (pronounced ēdz) was called crazy. People said that it was impossible to build a steel arch structure (strŭk´tūr) strong enough to carry trains over a river. Nevertheless, Eads went ahead with his plans. His bridge was finished in 1874. Today the bridge is still carrying heavy trains, trolleys, and automobiles across the river.

John R. Roebling (rōb´ling) was another great bridge-builder. He surprised everyone by flying a kite across the river at Niagara Falls. The kite carried a cord to the other side. This cord in turn pulled a steel wire. Thus he began to build the first suspension (sŭs-pĕn´shŭn) bridge in the United States. It was completed in 1855. Later, Mr. Roebling was chosen for a still more difficult job. He was asked to build a span across the East River from Manhattan to Brooklyn. He used thin steel wires, woven back and forth over the two high towers, much like the grapevine bridge.

The Famous London Bridge as It Looks Today

To John Roebling belongs the credit of making the wire cable suspension bridge a success. Earlier kinds of suspension bridges had used heavy chains. In Wales there is a bridge now over a hundred years old which has 16 chains to hold up the roadway. In Asia and the East Indies, you will find bamboo suspension bridges. Old grapevine bridges were also common. Many other kinds of suspension bridges have been built since the Brooklyn Bridge. Three others lead from the island of Manhattan. All of them are part of New York City's great system of transportation.

One of the most famous bridges in the world was London Bridge across the Thames (tĕmz) River. This is not the same London Bridge people cross today. The old bridge was torn down a little over a hundred years ago.

Built by a British monk named Peter in the twelfth century, the old London Bridge contained 20 stone arches and took 33 years to construct. Peter died before seeing his great idea completed. Nothing was then known about modern bridge engineering. His men drove piles by hand at low tide. The piles, being oak and elm, lasted more than

six centuries. The old London Bridge is often mentioned in old poems and stories.

The bridge soon had houses and shops clustered upon it. The wardens or keepers of the bridge collected the rents, and high ones, too. The central part of Peter's bridge was a drawbridge, which opened to let the larger river boats pass.

Peter's bridge was repaired many times. The houses upon it were finally taken down and its roadway widened. Because the arches were too close together to permit the larger boats to pass, the bridge was finally replaced in 1831 by another London Bridge. This is the bridge which crosses the Thames River today.

The ancient Romans were noted for their fine roads and bridges. Two thousand years ago, they built great aqueduct (ăk′wė-dŭkt) bridges. These were not only used as bridges but were also used to carry the water overland many miles to the cities. These structures were concrete arch bridges, built of native stone and clay, and have lasted for centuries. For many years, the fine old Roman bridges have been models for engineers to follow. You can still see some of them in Europe today.

This old Roman aqueduct, built almost 2,000 years ago, still stands in France today. Notice how the Romans built their arches.

How Bridges Differ

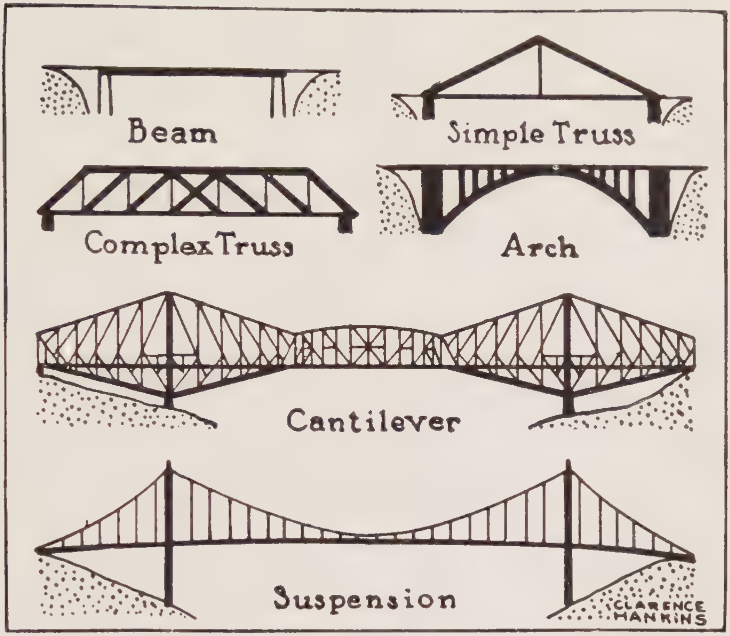
As you travel over one bridge after another, you may wonder why bridges differ so greatly. Some of them are made of wood, others are made of steel, and still others are built of stone. Bridges differ not only as to materials but they differ in design as well.

Early bridges in America were built largely of timber. Timber was abundant and cheap. It was also strong and durable. For these reasons, the old covered wooden bridges were widely used in New England.

Stone found in Pennsylvania was used for bridges along the old turnpikes. It was strong and was also abundant. By copying the Romans in their arch structures, the pioneers were able to use the stone found near at hand for the bridges which were necessary to the opening of roads to the West.

Iron and steel came into use much later as materials for bridgebuilding. Iron had to be mined, smelted, and hauled to the place where a bridge was to be built. This process

The Tower Bridge of London also crosses the Thames River.



Almost all bridges are built after one of these plans.

was expensive. So although iron and steel bridges are common sights today, they were uncommon sights a hundred years ago. The simple iron and steel bridges which you have seen over smaller waterways were the first attempts at using metal for bridges.

Simple iron and steel bridges are very common types of bridges over small streams throughout the country today. However, when longer and stronger bridges were needed, the bridgebuilder turned to the more massive structures. Improved kinds of steel finally came into use. Then, indeed, could engineers build longer and stronger bridges. The new kinds of steel are much stronger than the first steel that was made.

Bridge engineers have to think about other things besides materials. They must ask themselves, "What kind of bridge best fits the stream at this point?" If the river is wide, they build a different kind of bridge than if the river is narrow. If the river flows through a bed of rock, they choose to build another kind of bridge. If ships are to pass under the bridge, they may choose still another type. Through the years, men

have worked out certain kinds of bridges to fit certain uses. Some of them are shown in the illustration on page 9.

Suppose a bridge engineer is to build a bridge across a narrow river. He may choose simply to throw a beam of wood or steel across the stream. (See illustration on page 9.) You can easily see that such a simple beam bridge is much like the log which primitive man threw across the river long years ago. However, today's beam bridges are wide enough to allow a wagon or an automobile to cross. You can see beam bridges over small streams in our country today.

Perhaps another stream to be bridged is somewhat wider. A simple beam across the river might break in the middle. Perhaps the bridge is to be used by heavy trucks. The engineer needs to build a stronger bridge. He puts in other beams to support the bridge and makes a simple truss bridge. (See the second figure in the illustration on page 9.)

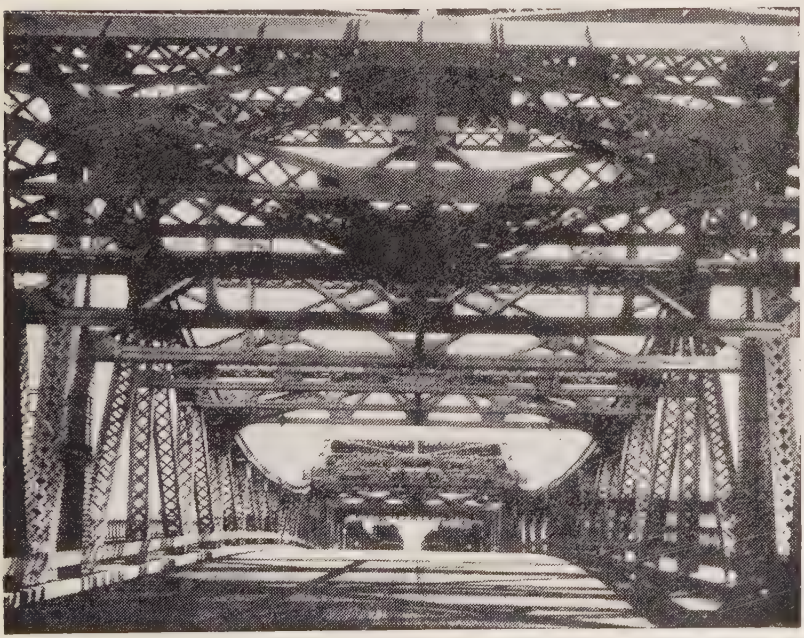
If the bridge needs to be still stronger, the engineer puts in more beams for support. He puts them in a criss-cross fashion. Then he has built a complex (kŏm-plĕks′) truss,

A part of the Key West Bridge is a series of beams.

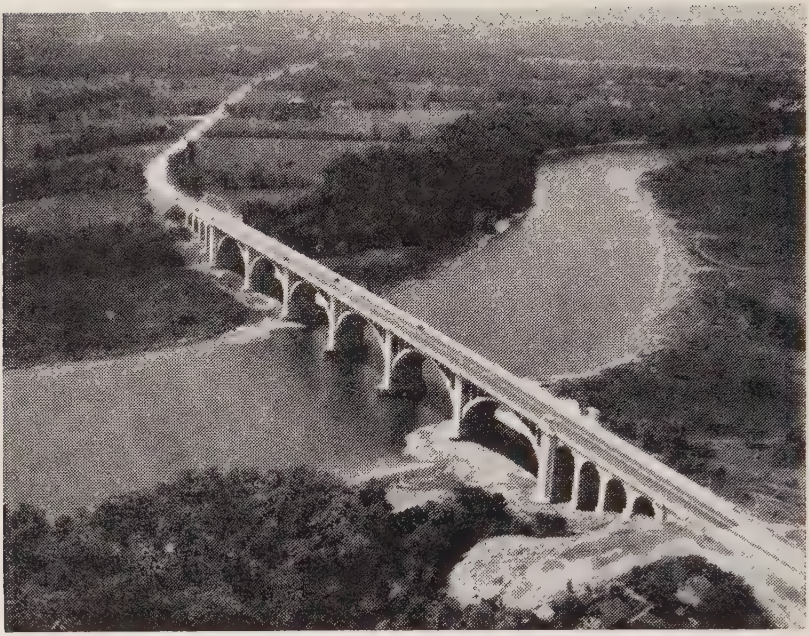
as shown in the picture. Complex truss bridges are also very common. You can probably find several on your way to school in the morning. They are often used for railroad bridges.

When primitive man found a stream that was too long to cross with one log, he might use two. If there was a rock in the middle of the stream, he would put one log from the shore to the rock. Then he would use a second log from the rock to the other shore. Today we build bridges in the same way. Instead of using a rock, men build huge supports or piers (pērs) out in the middle of the stream. Then a long series of bridges is built from one support to another, just as primitive man might use one log after another. This kind of bridge is shown on page 10.

Another kind of bridge is the arch bridge, also shown by the illustration on page 12. This is the kind of bridge built by the ancient Romans. This bridge had two advantages over the beam. The arch could be erected in parts, which stayed in place when the center stone was set. The arch



BRIDGE BETWEEN ALAMEDA AND OAKLAND, CALIFORNIA
The steel work overhead helps support the bridge.



College Bridge, at New Brunswick, New Jersey, is a concrete arch bridge, modeled after the Roman bridges.

was stronger than a beam of the same length. You will see arches holding up the roofs of many great churches.

The arch bridge has beautiful curves to carry its load. Bridge engineers have learned exactly how they must bend the arch in order to make the bridge strong. The Romans built these bridges out of stone. Today engineers build them out of concrete or steel. If the stream is narrow, only one arch may be necessary. If the stream is wide, huge supports may be built in the middle. Then a series of arches is built from one pier to another. A series of stone arches was used in the railroad bridge in Switzerland shown on the cover of this book.

The cantilever (căn´tĭ-lē-vẽr) bridge, also shown in the illustration on page 9, is often built over a river where a wide space must be left for ships to pass below. The cantilever bridge is sometimes said to be the "bookshelf bridge." Find a bookshelf that is supported upon the wall by brackets. Imagine that another bookshelf of the same kind could be put up opposite it, with the ends of the two shelves

touching. Both shelves would be supported by the brackets on the wall. They would also support each other at the point where the shelves touch. A cantilever bridge is built in a similar way and is supported in the same way.

When a cantilever bridge is to be built, the first task is to build a firm foundation on either side of the stream. These foundations take the place of the brackets on the wall. Then, from either side of the stream, workmen built the bridge structure. The picture on this page shows how they do this. As they go farther and farther out into the stream, each part of the bridge must be placed so that it is supported by the foundation on shore. Finally the two ends meet and are woven together. Now the two ends support each other in the middle, besides being supported by the foundations on shore. Thus, the cantilever bridge is one of our strongest bridges. The Firth of Forth Bridge shown on page 22 is a cantilever bridge.

Near the beginning of this book, it was said that some great bridges today are built like primitive bridges. For in-

THE SAN FRANCISCO-OAKLAND BAY BRIDGE BEING BUILT

The picture shows how a cantilever bridge is constructed.

stance, some bridges are copied after the grapevine bridges of long ago. Such bridges are called suspension bridges. They are suspended or hung across the streams. The George Washington Bridge shown on page 19 is such a suspension bridge.

Suspension bridges are very beautiful. They are used not because they are beautiful but because they are the most suitable for long spans. Yet suspension bridges are costly and are difficult to build as John Roebling found out years ago.

First of all, great foundation piers need to be built on opposite sides of the river, or even out in the river if the bridge is to be made in several sections. Then the costly job of spinning the great cables across the river is begun. John Roebling began his work by flying a kite across the river. The kite carried a cord. Today men have other ways of carrying the first cord across the river. A temporary cable is swung across the river. Spinning wheels travel back and forth on this cable. They drag great lengths of wire behind them until all the wire that is needed has been spun. The wires are then pressed and bound together in great cables.

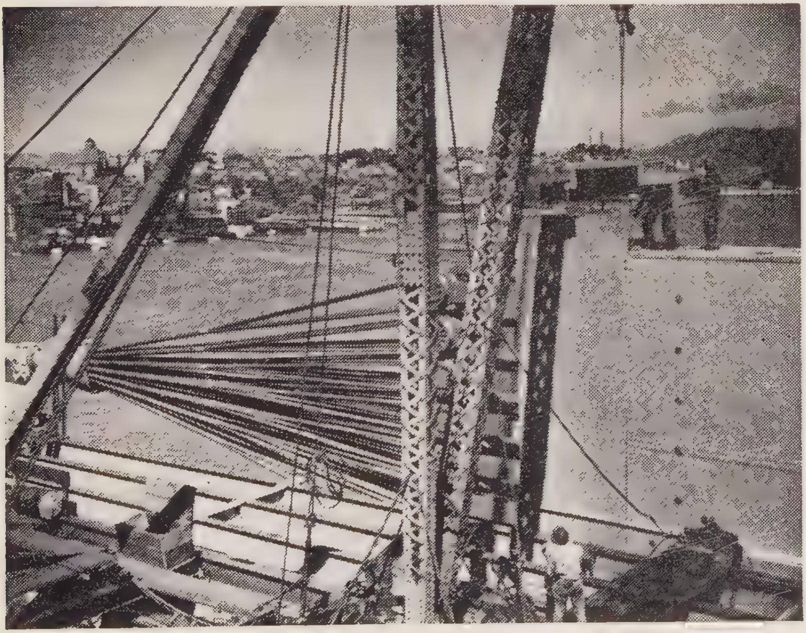
The Bronx Whitestone Bridge is a suspension bridge. Strong cables support the bridge after the manner of the woven grapevine bridge.

Finally a roadway for the bridge is hung from these cables.

Now turn back to page 9 and from the illustration review what you have learned about the building of bridges. The beam bridge is like the log thrown across a stream such as early man used. The simple truss and the complex truss bridges are like the beam bridge, except that they have extra supports. The arch bridge carries its load like a man with a bent back. The cantilever bridge is the "bookshelf bridge." The suspension bridge is modeled after the swinging grapevine. Now can you tell which kinds of bridges have been built in your community?

Bridge engineers have to think about other things, too. If tall ships go up and down the river, in some cases bridges would have to be so high that they would be very expensive to build. Then the engineer must design some kind of bridge that can be moved aside to let ships pass. Such a bridge may swing or lift up to make room for a passing ship. There are several different kinds of such movable bridges.

One of the movable structures is a swing bridge. It has a



WORKING ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE
Notice how the great cables are made from smaller wires.

This is a jackknife bridge. It opens to let ships pass.

central span which swings around at right angles to the fixed parts of the bridge. In this way boats can pass on either side of the central section. You can see that the swing bridge is useful in only those streams where the channel on either side is wide enough to allow the craft to pass between it and the shore.

Many streams are too narrow to permit swing bridges. In this case a lift bridge is often built. Sometimes the span over the channel of the stream is separated in the middle, and the two halves lift into the air in the center to make room for the tall masts and stacks of the ships.

Another kind of lift bridge has a span fixed at one shore but free at the other. This span opens like a jackknife when boats signal. The small bridges over the moats of ancient castles worked in this way.

There is still another kind of lift bridge where the central section operates much as a store elevator does. It raises straight up. Such a bridge is called a vertical (vûr′tĭ-kăl) lift. These bridges are often built over ship canals because they allow larger boats to pass under them easily.

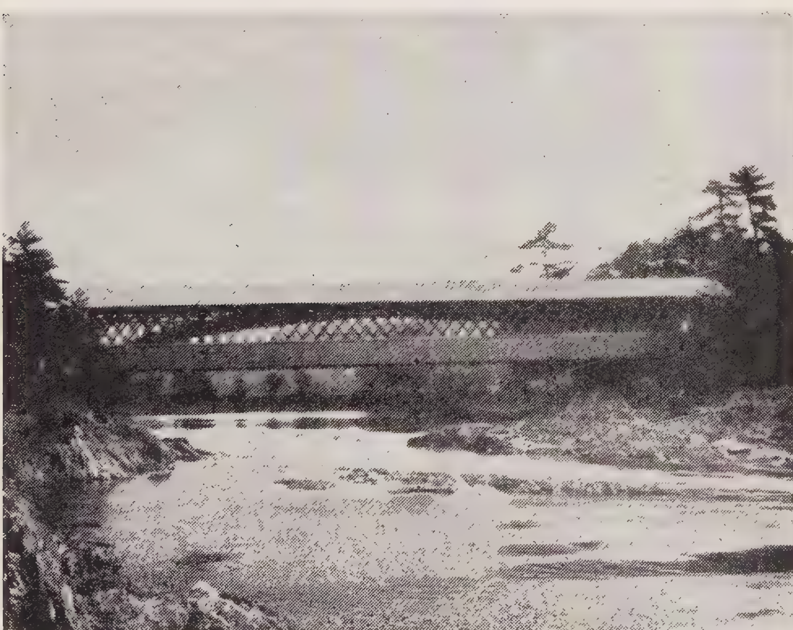
Covered Bridges

Perhaps no bridges in our country today are quite so quaint and beautiful as the covered bridges of New England. Only a few of these quaint structures remain, however. Many of them have been washed away by floods. Others have become too narrow or too weak to carry the heavy traffic which now goes their way. Hence, sturdier and larger steel and concrete structures have replaced them.

Long ago, Rome built covered bridges but they were quite unlike the ones found in New England. One of these famous Roman bridges led to the Vatican (văt′ĭ-kăn) City where the Pope lives. This bridge was said to have had a bronze roof held up by 42 pillars.

In England long ago, there were covered bridges with shops and houses on either side. There was an open-top roadway for horses. This roadway ran through the center. The shop parts of the bridge were covered, and the villagers gathered there in the evening to gossip with their friends.

The New England covered bridges were built entirely of



Notice the lattice work on this bridge in New Hampshire.

timbers hand hewn for the purpose. They were built in the late seventeenth and eighteenth centuries. Since at that time little was known of modern bridgebuilding, we must pay tribute to these builders for their fine workmanship. The bridges were covered with steep roofs, probably to keep out the weather and thus make the timbers last longer. The floors were laid with loose boards. Later, the boards were nailed to the heavy timbers beneath them. Since timber was plentiful and labor was cheap, these bridges were built at very low cost. They ranged in cost from $300 to $600.

Sometimes the bridges had a partition running through the center to separate the two lines of traffic. A few of the old bridges had paths at one or both sides for pedestrians. Some of these bridges were 400 feet long. Some of them have served their communities for a century or more.

The Connecticut River once boasted many covered toll bridges. The tolls were collected by exacting keepers. No set rate was charged. It was often left to the keeper how much he would ask. There are records which show what some of the fees were as follows: foot passenger, 2c; horse, 4c; horse and rider, 6c; two horses, 13c.

The people objected to paying so much money to the bridge owners. It is said that a bridgekeeper sometimes took in $1,000 a month from travelers. Many towns in New England bought the bridges and made them free.

Some old covered bridges had windows at frequent intervals to light the roadway inside. Others had lattice work along one or both sides to admit light. Sometimes there was a row of windows just under the steep roof where light came through. Many of the old bridges had a kerosene lantern hung inside for light at night. The wood today is worn down in many of them by the striking of thousands of matches. What tales these old landmarks could tell of the passing of time!

It is little wonder that the people of New England came to love their covered bridges and to regret their passing. In 1927, the great flood carried away more than 1,400 covered and small bridges in Vermont alone. Those that have withstood the floods are one by one being abandoned or torn down. Stronger bridges are now carrying the traffic that once clattered through the quaint old roadways.

The George Washington Bridge crosses the Hudson.

Famous Bridges of Today

The George Washington Bridge is indeed a splendid example of the combination of strength and beauty in bridge-building. You may have crossed it on your way to New York City. It spans the Hudson River and carries thousands of busy people in busses and cars in and out of that great city.

The George Washington Bridge is one of the longest suspension bridges in the world. It has two high steel towers reaching 595 feet above the water. Over the towers are woven thousands of strands of thin steel wire. Hundreds, yes, thousands of miles of wire are woven back and forth across the river. These wires are bound together and wrapped securely into four strong cables. Each cable is 36 inches in diameter (dī-ăm′ė-tẽr). The wide roadway of the bridge is supported by means of struts which are fastened all across the bridge to both the roadway and the cables.

There it stands, a monument indeed to the courage and foresight of the men who have overcome grave difficulties and have given to the world such a beautiful structure.

The Triborough Bridge is really three big bridges.

The world's longest bridge is the San Francisco-Oakland Bay Bridge (shown on page 25). This bridge, including the approaches, is 8¼ miles long.

The Triborough (trī´bûr´ō) Bridge is in fact three bridges joined together so that the thousands of people from the three parts, or boroughs, of New York City can go and come more easily. There is one long span which is a suspension span and crosses the East River at Hell Gate. There are two smaller spans, one running to the Borough of the Bronx (brŏngks) and the other going to the Borough of Manhattan (măn-hăt´ăn). This great bridge, which was finished in 1936 cost over $60,000,000 and is being paid for by tolls which are charged to all passengers.

Running alongside the Triborough Bridge is the great steel arch Hell Gate Bridge. There are two long approaches leading up to the arch span of Hell Gate. This bridge was finished in 1917 by the Pennsylvania Railroad. The Pennsylvania Railroad in this way connects with the New Haven and Hartford Railroad. Both roads benefit because their passengers and freight can go from north to south more quickly.

Hell Gate Bridge is one great steel arch across the Hudson.

The steel pieces used in the arch part of the bridge are among the largest pieces of steel ever used in any building. Two freight cars were needed to haul each of the four largest pieces of steel. The arch was built out in two sections, one from each shore. So carefully did the engineers plan that the two halves met in the middle of the span perfectly.

The Golden Gate Bridge is at present the longest suspension bridge in the world. It is 4,200 feet between the two towers. It has the tallest bridge towers, too. They are 746 feet high. The bridge stretches across part of San Francisco Bay. The cables contain 80,000 miles of wire which was woven back and forth between the two piers. The bridge is more than a mile and a half in length and cost $35,000,000.

Sometimes a suspension bridge cannot be built over wide rivers or bays. Often a cantilever bridge is erected instead. The Firth of Forth Bridge in Scotland was for years the longest cantilever bridge in the world. It was built in 1889 and is 8,300 feet at its greatest length.

At Quebec, Canada, there is a great cantilever bridge over the St. Lawrence River. While it was being built, a section

of it crumpled and carried almost a hundred workmen to their death. A second attempt also failed and killed several more men. After 12 years of work, the third attempt proved successful. The center part was lifted into place by powerful hydraulic (hī-drô´lĭk) jacks. It took four days to lift the span 150 feet and put it into place to complete the structure. You may be sure that those engineers and workmen were relieved when that mountain of steel was finally made secure.

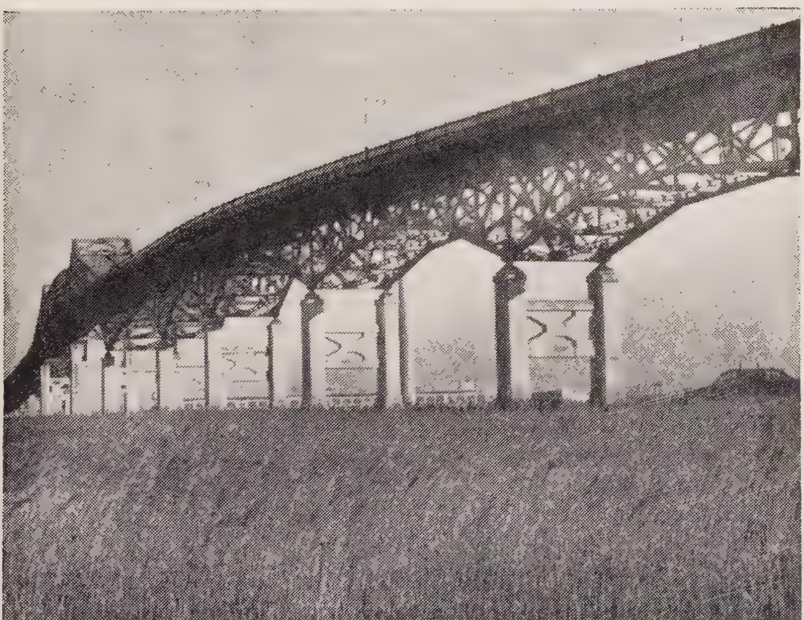
The Carquinez (kär-kē´nĕs) Strait Bridge across an arm of San Francisco Bay is also a cantilever structure. It has six piers which were sunk 135 feet below swift tide water. It is planned to withstand the earthquakes which sometimes occur in that area. Powerful steel cables lifted the sections into place in 30 to 35 minutes. Contrast this with the time required to lift the span of the Quebec Bridge.

Today as never before in our history we are facing a serious traffic problem. Automobiles are more numerous than ever before. Trucks now carry cargoes that used to be shipped by rail.

A battleship passes under the Firth of Forth Bridge.

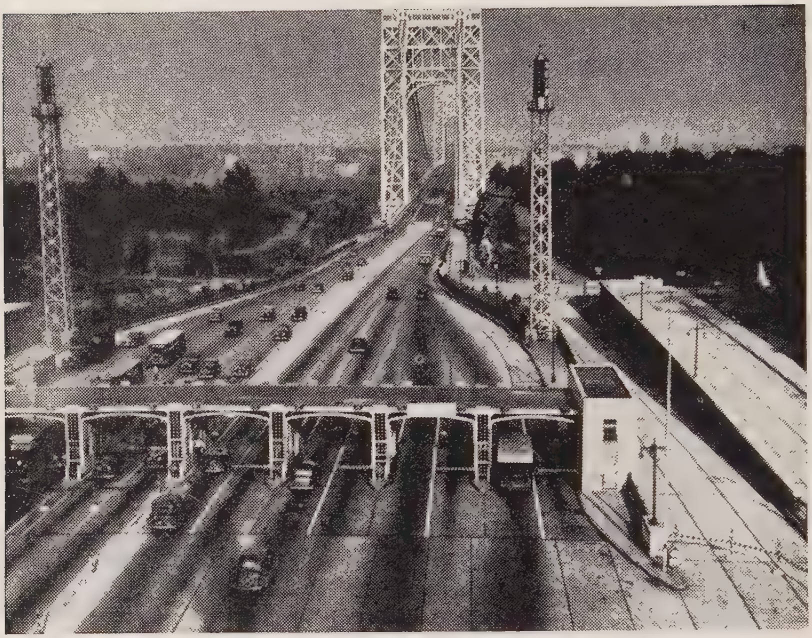
Road engineers have met this problem in some instances by erecting long elevated roadways. The Pulaski (pŭ-lăs´kė) Skyway is such an elevated highway. It stretches from the Holland Tunnel outlet across the swamps, marshes, and streams of New Jersey. Part of the long elevated highway is a mass of concrete. Part of it consists of steel bridges stretching across the lowlands or over the rivers of New Jersey. This elevated bridge skyway has made entrance to New York City a much safer and easier task. It carries thousands of fast-moving vehicles in and out of the city daily.

Such super-highways are now being built in various parts of the country. Usually these highways lead into and out of large cities. The traffic problem in many large cities is becoming more and more serious. The super-highway is one way by which heavy traffic can be more easily handled. The super-highway is really a series of bridges and roadways combined. When the bridge engineer plans the highway, however, he has to make plans for building a series of bridges. Thus, we can consider the Pulaski Highway, as well as other super-highways, as great bridges.



A Part of the Pulaski Skyway Leading Into New York City

How a Big Bridge Is Run



Automobiles stop at the tollgates of the George Washington Bridge.

When you cross a big bridge in an automobile, you will see only a few men near the entrance. There is the man to whom you pay a toll of perhaps 40 cents. There may also be a police officer on a motorcycle near by. Yet these are not all the men who are needed to run a big bridge. Hundreds of other men may be working where you cannot see them. Let us see what these men do to keep the big bridge running. Let us take the San Francisco-Oakland Bay Bridge as an example.

When you cross this bridge, you must pay a toll of 40 cents.* About 25,000 automobiles and trucks pay this toll every day. Thus, the tollkeeper collects about $10,000 every day. This is a large sum of money, probably much more than many of the stores in your town take in each day. Great care must be taken that this money is not stolen.

The officer who collects the money is protected by bullet-proof glass and steel walls. He puts the money in a bag and

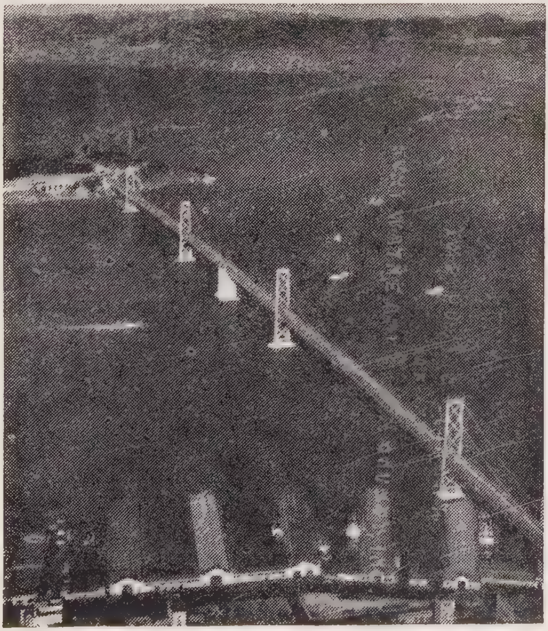
*The toll may soon be reduced to 25 cents.

slides it down a chute (shōōt) to a room below the roadway. Here is a room that looks much like a bank. Here other men are at work keeping records of the money received. Men are standing guard. Inside are weapons as well as telephones for calling help if needed.

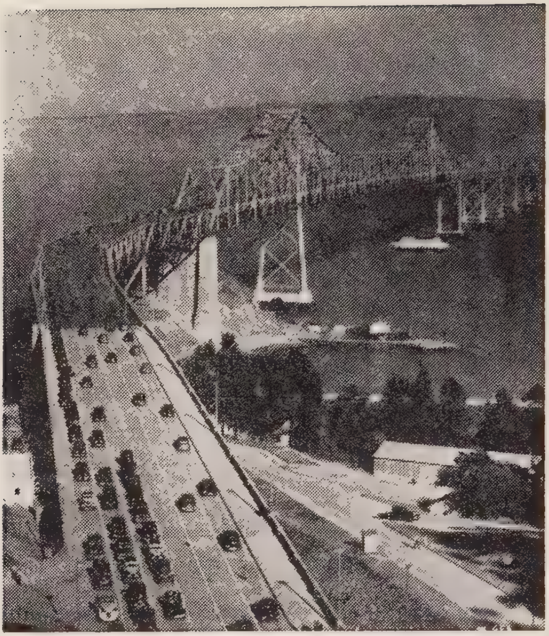
What would you do if you were to run out of gasoline or if your car were to break down while you were crossing the great bridge? Traffic must be kept moving if 25,000 cars are to cross the bridge in one day.

To help you in case of trouble, you would find telephones at short intervals all along the bridge. You might break the glass over one of these, and telephone for help. In a few minutes a service car will come to help you. It may bring gasoline or, if necessary, it will tow your automobile off the bridge and out of the way of traffic. The big bridge has its own garage with many employees. You do not see the garage when you cross the bridge, but the men are there waiting to help in case of trouble.

One day a truck was crossing the bridge when the driver discovered that the load back of him was on fire. He stopped his car, and used the near-by telephone to call for help.



The San Francisco-Oakland Bay Bridge is the world's longest bridge. It goes from San Francisco to Yerba Buena Island, then to Oakland and Berkeley.



About 25,000 automobiles and trucks cross the San Francisco-Oakland Bay Bridge every day.

Soon a fire engine came and put the fire out. The big bridge has its own fire department to put out such fires.

The bridge has a long telephone system. A police officer carefully watches over the cars that cross the bridge. If he discovers that a stolen car is crossing, he can telephone to the other end of the bridge and the car will be stopped there. Telephones along the length of the bridge connect with the central garage and police station. Thus, the bridge is like a big store, with the many parts connected by telephone.

A big bridge costs many millions of dollars. Great care must be taken to protect this valuable property. On the high towers, there are signal lights to warn airplanes away. There are also lights on the piers to guide ships on the water below. A great lighting system is needed. Many electricians are at work every day to keep the system in order.

The bridge has many painted parts. High up over San Francisco Bay, the big bridge is beaten upon by all kinds of weather. When the paint is weathered away, painters must be employed to put the bridge in good condition once more. The whole bridge has to be repainted every five or six years. A big staff of workers is needed for this job.

Altogether, about 250 men are employed every day on the San Francisco-Oakland Bay Bridge. When you cross the bridge, you see only a few of these. Yet the rest of them are needed to keep the bridge running without danger to passing motorists and to keep the valuable bridge safe.

Accidents can happen to a big bridge just as they may happen to any large building. The San Francisco-Oakland Bay Bridge has already withstood one earth tremor without damage. The bridgebuilders believe that the bridge has been so built that it will withstand others. There may also be danger from ice jams, floods, tides, or fire. In case of any such emergency, the workers on the bridge will undertake to repair the damage and to call for help from outside if necessary.

Most large bridges are owned by the State where they are located. The San Francisco-Oakland Bay Bridge is owned by the State of California. The workers on the bridge are working for their State. The money to pay for the bridge was raised by the State of California. From the tolls paid by motorists, the State hopes finally to get the money back again.

This man helps to keep the great bridge in good condition. About 250 men are needed to help run the great bridge.

Through Many Tunnels

Now, what of tunnels? They are also a part of that great system of transportation which has grown up all over the world. They are quite as important as bridges for they carry railroad trains through high mountains, they carry water through great aqueducts to large cities, and take vehicles of all kinds under rivers. We could not do without them.

Tap, tap, tap go the tools of the men who risk their lives to build these tunnels. These "sand hogs," for that is what they are called, work under heavy air pressure beneath the surface of the ground. They must go into and come out of the tunnels gradually through air chambers so that they will not get sick by changing the air pressure on their bodies too rapidly.

Tons of water and mud and rocks are above and all around these brave workers. At almost any moment there is danger of the earth above them breaking through and killing them. Slowly the tunnel grows longer and longer by the efforts of the "sand hogs." At last they "hole through." What a cele-

These "sand hogs" are working below the Hudson River.

This tunnel in London, England, is used only for carrying mail.

bration there is then! These men have overcome danger and have succeeded in building tunnels all over the world.

The first tunnel in America was built in Pennsylvania. It was dug about a hundred years ago to get coal from the mines.

Boston was the first city in the United States to build a subway, which is a special kind of tunnel. London, Berlin, Paris, and Moscow all have subways. The ones in Moscow are perhaps in many ways the finest in the world.

New York City has a network of tunnels. Besides its long subways, which carry almost two billion passengers every year, it has tunnels for water, gas pipes, sewers, telephone and telegraph wires, automobiles, and even for mail. Tunnels for automobiles and other vehicles are called vehicular (vē-hĭk′ū-lẽr) tunnels.

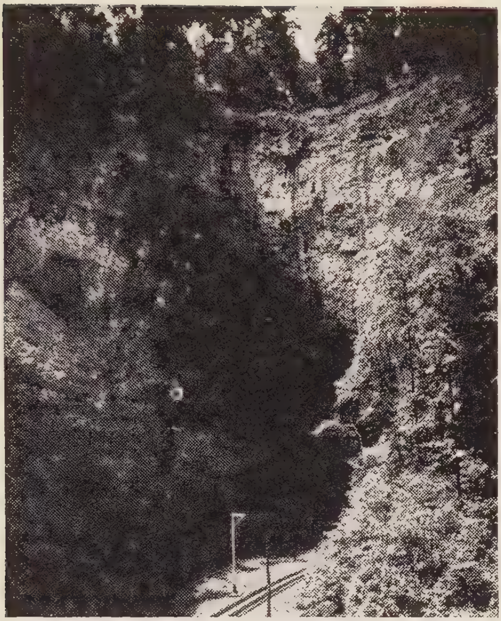
Two vehicular tunnels cross under the Hudson River. One is the Holland Tunnel, which carries 13,000,000 cars each year between New York and New Jersey. This tunnel was opened in 1927. During the first day 50,000 cars passed through the tunnel, carrying 180,000 passengers. Almost

Automobiles Going Into the Great Lincoln Tunnel

$25,000 was collected in tolls on that first day. Passenger cars now whiz through the tunnel carrying many busy people. Trucks rumble through it loaded with vegetables, fruit, and other produce coming into the city markets to supply food for the millions of hungry mouths in New York. In 1937 a second vehicular tunnel under the Hudson was opened. This is the great Lincoln Tunnel.

Railroad companies use tunnels to get their trains through the mountains. Such tunnels are built at an enormous cost, but without them the stream of transportation would be delayed in many places. There are several long railroad tunnels through the Alps mountains in Europe. The St. Gotthard (gŏt′ẽrd) is one of the most famous of these tunnels. It is more than nine miles long. This tunnel was built at a cost of $11,500,000.

Another famous tunnel through the Alps is the Simplon (sĭm′plŏn) Tunnel. It is over 12 miles long. In digging it the workers met with many difficulties. Hot springs, cold springs, and dangerous gases had to be conquered. Mont Cenis (môn′sẽ-nē′) is another of the famous Alps tunnels.



Natural Tunnel
in Virginia

It connects France with Italy. It was the first of these great tunnels and took 13 years to complete. When the two parts of the tunnel met some thousands of feet below the lofty mountains, they were only an inch out of line.

In the United States there are several long railroad tunnels, also. One runs under a part of San Francisco Bay at San Francisco. Another is the Moffat (mŏf′ăt) Tunnel between Denver and Salt Lake City. Both of these tunnels carry hundreds of freight and passenger cars to their journey's end.

There is an international tunnel which runs from Detroit, Michigan, to Windsor, Canada. It is the first tunnel built to connect two countries of North America. This tunnel was built in 20 separate sections on land. Each section was floated into place and then sunk into a ditch already dug in the river bed.

The building of tunnels is not a new feat. As long ago as 4,000 years tunnels were built by the Babylonians (băb-ĭ-lō′nĭ-ăns). All the Mediterranean peoples seem to have dug tunnels to get to the tombs of their beloved rulers. Some 1,800 years ago the Greeks began building tunnels for water.

Things To Do

1. Find out as much as you can about the history of the bridges in your own neighborhood.
2. If there is a bridge being built near your school, watch it. Take pictures of it as the work progresses. Make a scrapbook or a diary of the new bridge.
3. Find out where the pioneers forded the streams which are in your neighborhood.
4. Construct different kinds of bridges for an exhibit.
5. Make a pictorial floor map of a river and place your bridge models upon it. Place boats upon the river. Let busses and cars cross the bridges going to and from the different parts of the city.
6. Make a collection of poems about bridges. Be sure you find "Horatius at the Bridge." It is a thrilling adventure.
7. Collect pictures of various kinds of bridges. Make a bridge "time line" by pasting them on a long strip of wrapping paper. Paste them in order of their construction dates from early days until now. Use your bridge "time line" as a movie to be shown to visitors to your school.
8. Make a model city in one corner of your classroom. Show how bridges and tunnels can be used to help solve traffic problems. Be sure that the children do not have to cross highways to get to school. Tunnels and bridges for foot passengers are now being built to aid in safety projects.
9. Plan a series of bridge posters. Draw pictures of different types of bridges. Display them on the bulletin board.
10. Look up the lives of John Roebling, James Eads, and John Holland, who are famous as great bridge and tunnelmakers.
11. Write stories and poems about bridges or tunnels. Use these for an assembly program.
12. Study a United States map. Locate the great waterways. Show where the bridges mentioned in this book cross these streams. Locate other big bridges.
13. Have someone in your class write to the American Institute of Steel Construction, 200 Madison Avenue, New York City, and request the loan of their film dealing with bridge construction.
14. Make the following kinds of bridges by using pasteboard boxes: beam bridge; truss bridge; suspension bridge; cantilever bridge; bridge with one arch; bridge with a series of arches; covered bridge.
15. By pasteboard models, show how part of a bridge may be lifted up to let ships pass underneath.
16. Find out if any plans are being made for new bridges or new subways for your city. If bridges are to be made, ask an engineer what type is most practical.
17. See Compton's Pictured Encyclopedia, Volumes A, B, C, D, S, T, W for more pictures of bridges and tunnels.